

Refractive index determination from dual polarization scattering measurements of aerosols

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1. INTRODUCTION

Known refractive indices of aerosols vary from 1.1 to 2.75 in the real part and from 0 to 1.46 in the imaginary¹⁻⁴ due to their complex physical and chemical composition.

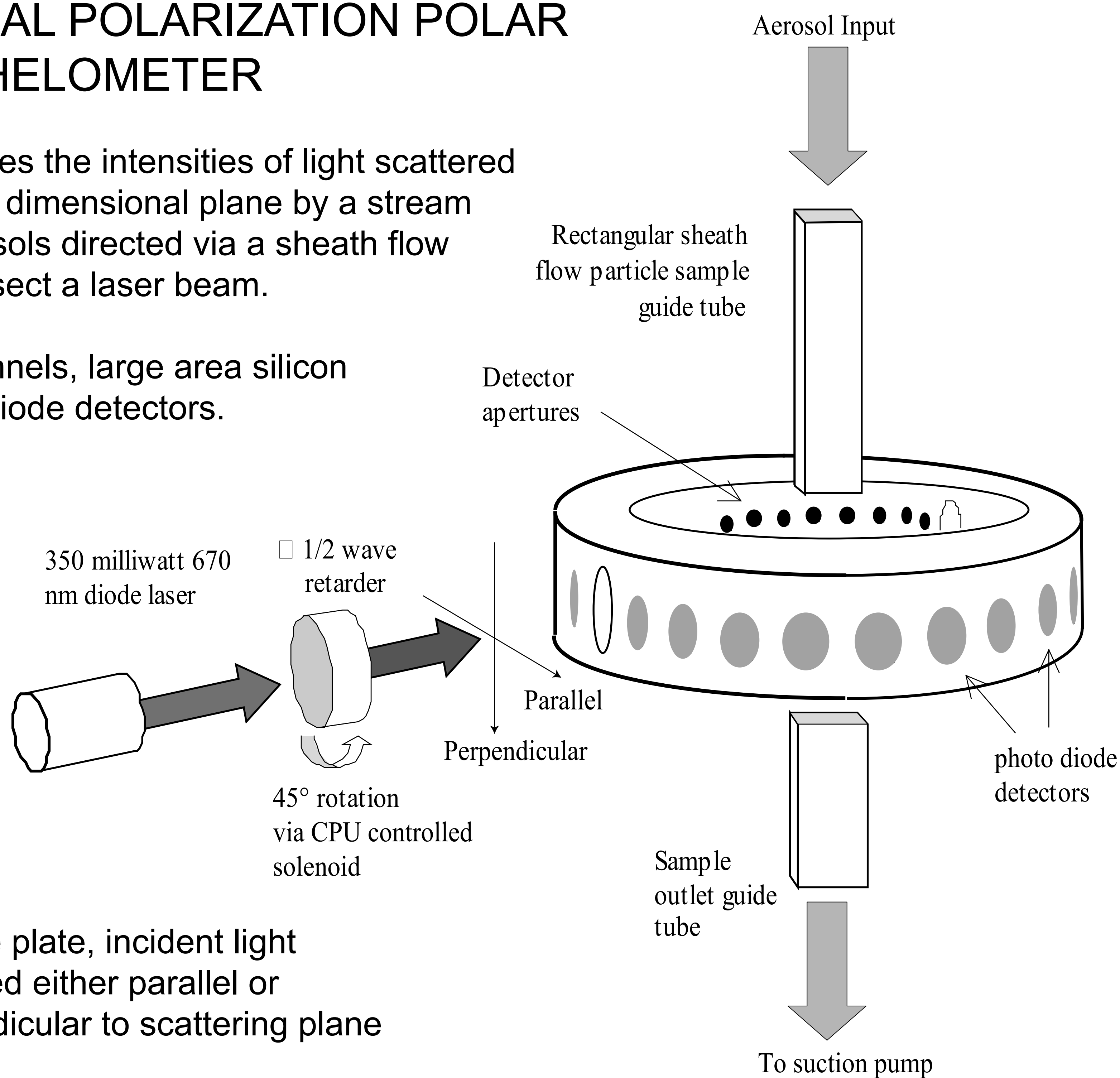
We have developed an instrument and a methodology to determine the real and imaginary refractive index of suspended aerosols.

Here we present some preliminary measurements made from the dual polarization polar nephelometer during an extensive aerosol photo chemical experiment conducted during the summer of 2006 in Los Angeles.

2. DUAL POLARIZATION POLAR NEPHELOMETER

Measures the intensities of light scattered into a 2 dimensional plane by a stream of aerosols directed via a sheath flow to intersect a laser beam.

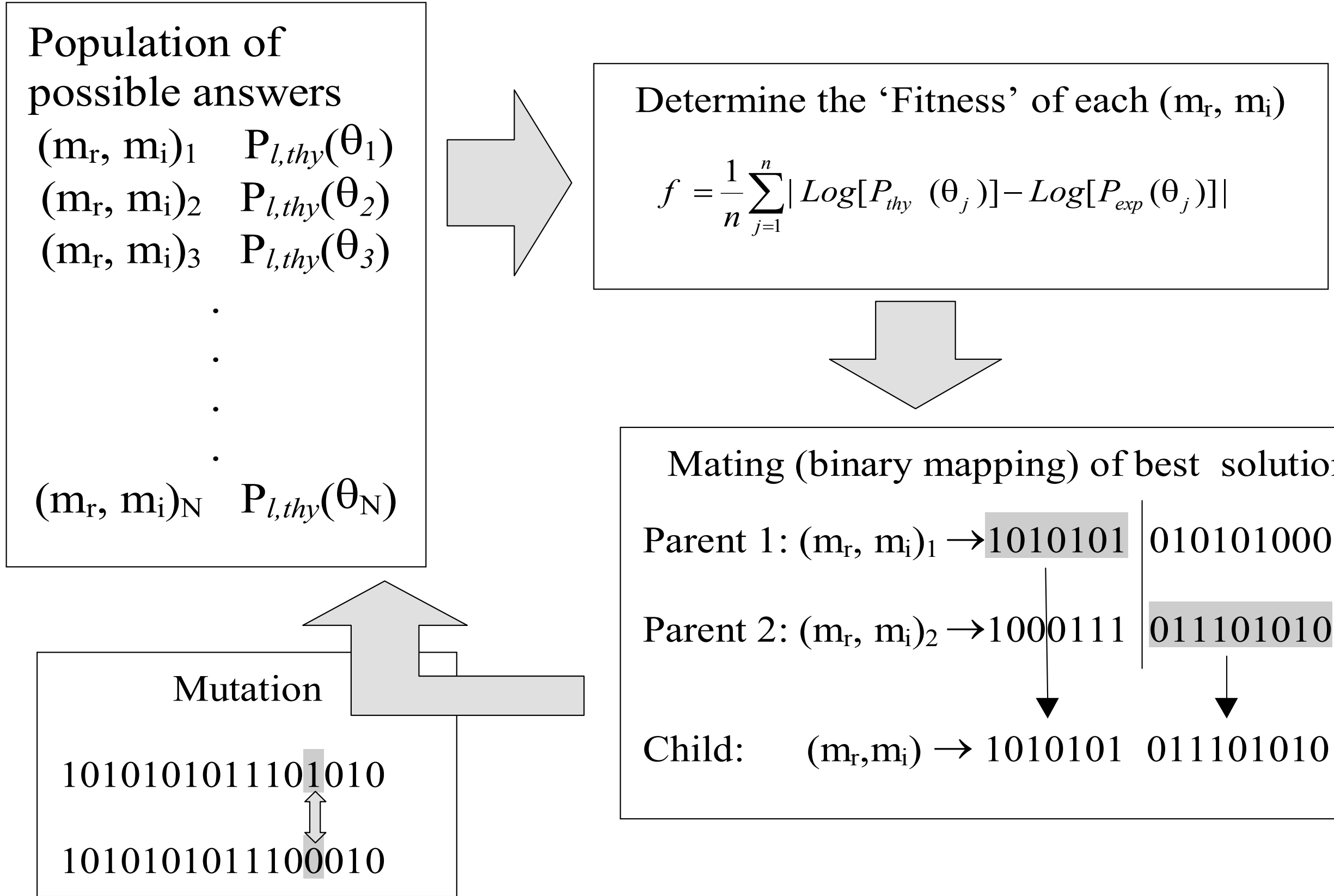
21 channels, large area silicon photo-diode detectors.



½ wave plate, incident light polarized either parallel or perpendicular to scattering plane

On board embedded PC for control and data acquisition

3. GENETIC ALGORITHM RETRIEVAL OF REFRACTIVE INDEX



Intelligently searches the solution space by 'mating' the genetic representation of the best solutions.

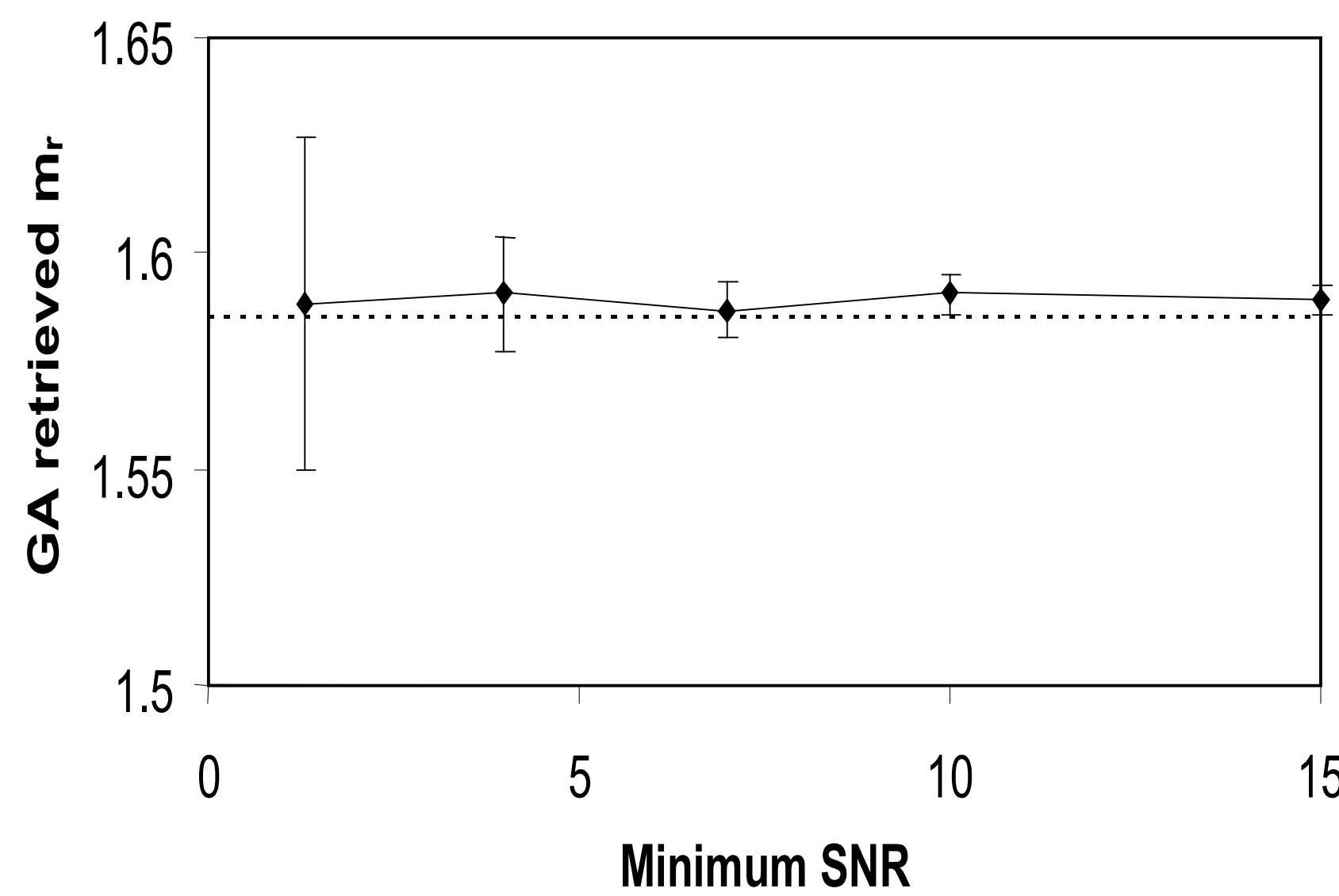
Iterations occur until the fitness parameter ' f ' reaches a certain level or to a preset number of 'generations'.

Not an analytical solution, therefore we are not limited to inversions based on the spherical particle assumption.

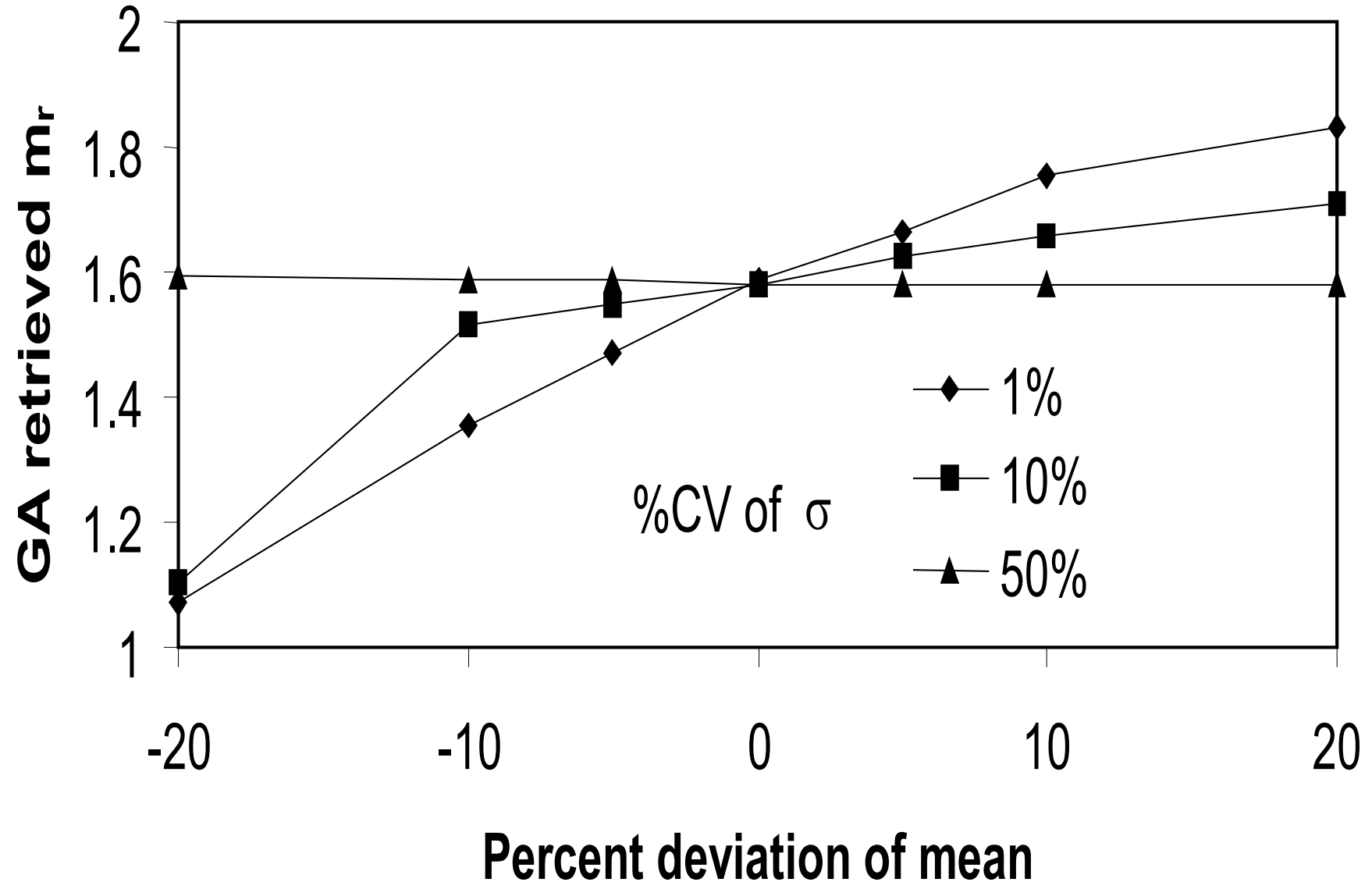
Other fitness parameters added via;

$$f = \frac{f_1 + f_2 + \dots + f_n}{n}$$

4. INDEX RETRIEVAL ERRORS

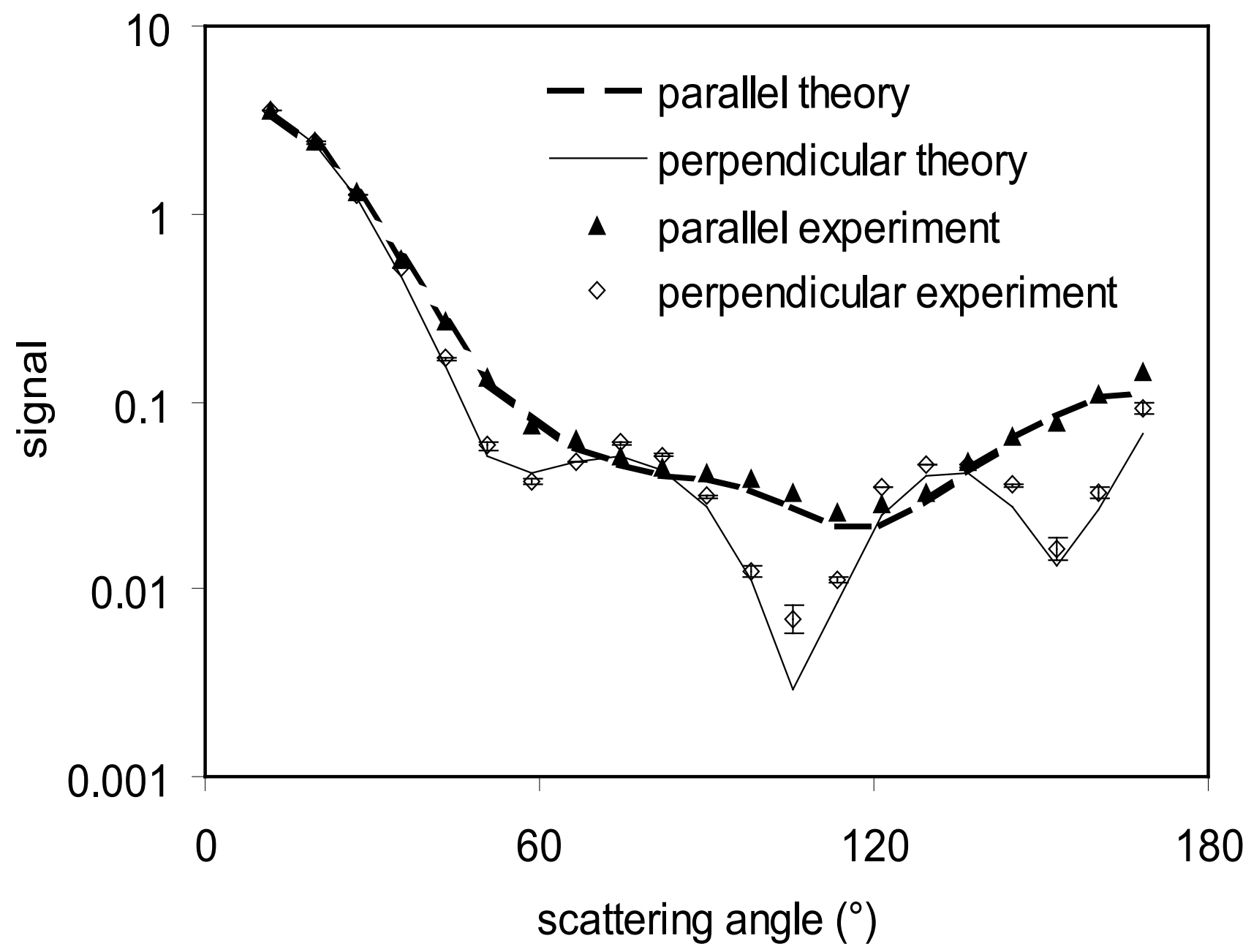


The range of the GA retrieved real refractive index (m_r) from Mie generated synthetic results with random levels of noise based on the SNR. The lowest instrument SNR observed in practice is about 1.4 where the retrieved m_r is correct to within +/- 0.03.



The range of the GA retrieved m_r from Mie generated synthetic results with various errors in the mean (μ). The %CV ($=100 \times \sigma / \mu$), is used as a measure of the width of the distribution. As the distribution width increases, the error in the retrieved m_r is reduced as the scattering properties become less dependent on the distribution.

5. CALIBRATION AND TEST OF THE INDEX RETRIEVAL



The measured and calculated scattering properties of calibration polystyrene latex spheres.

Average radius = 403 nm

$\sigma = 5.64$.

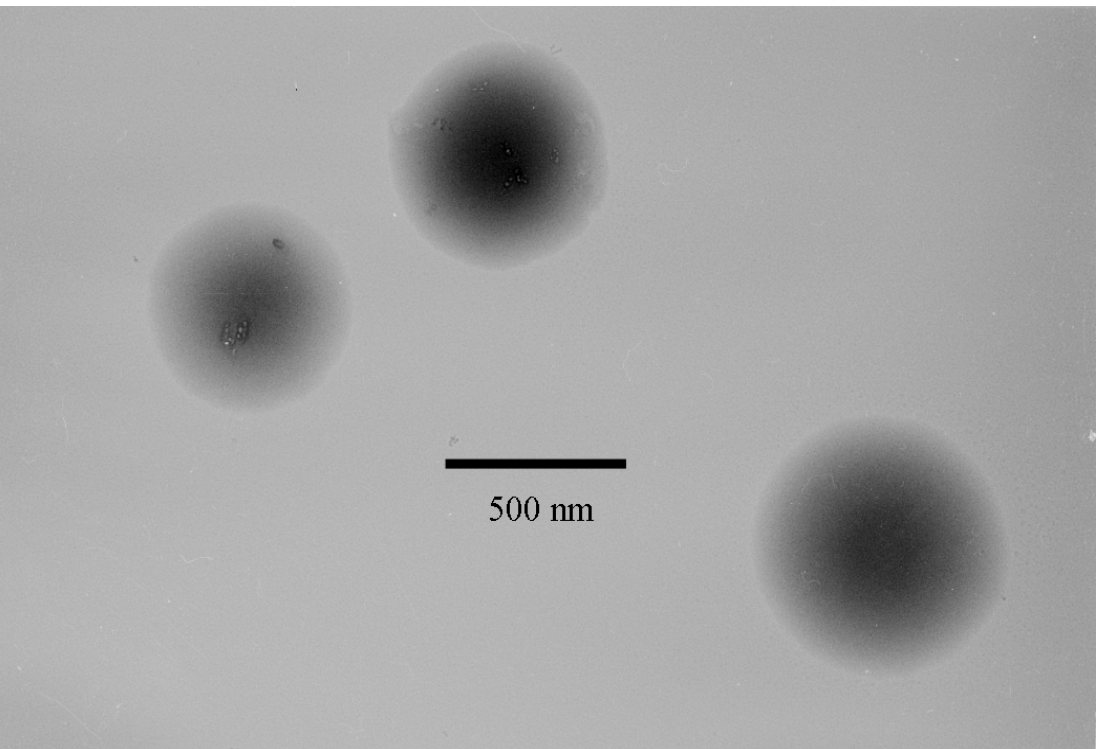
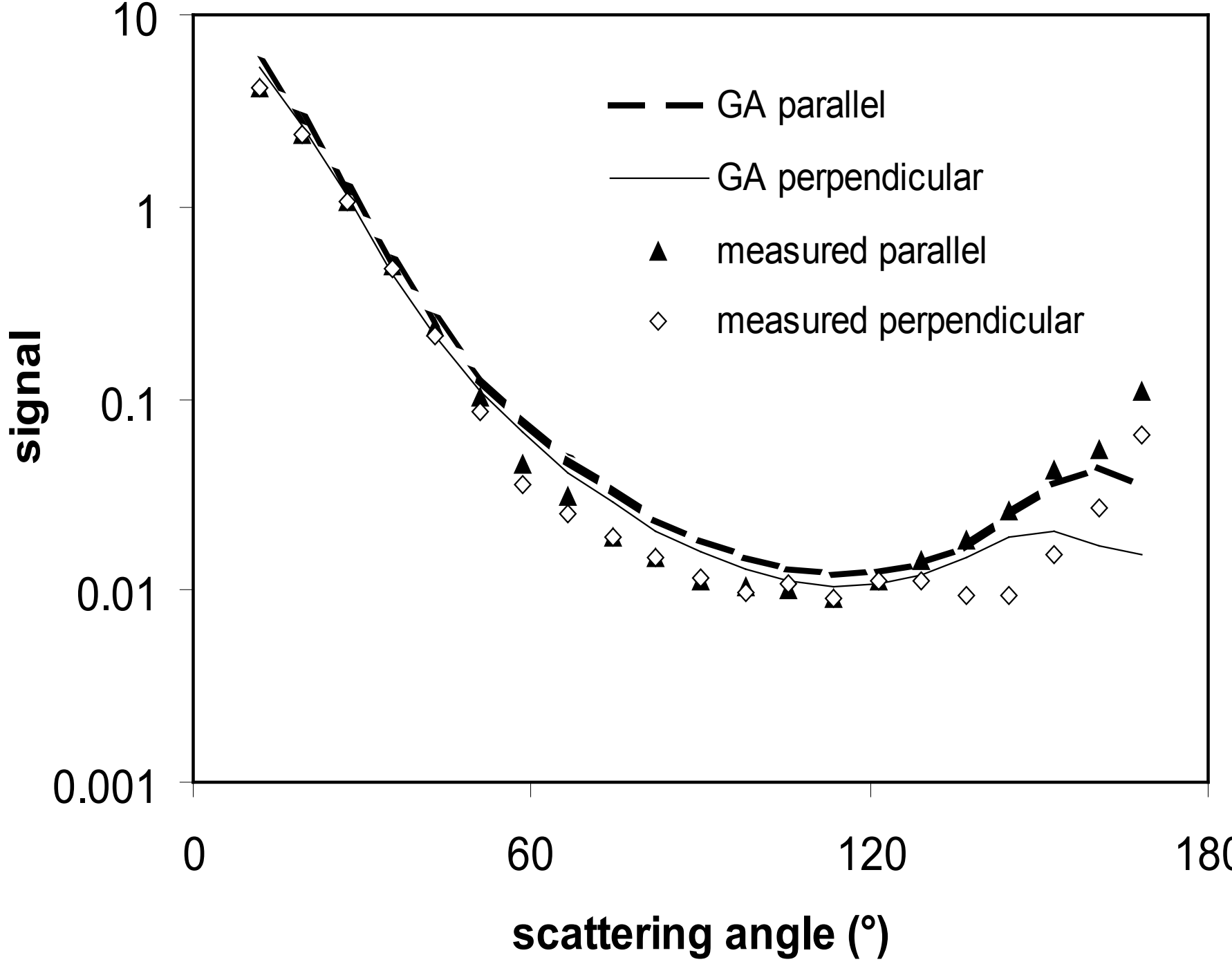
m_r is 1.5854.

Error bars are based on the σ of 15 separate measurements.

GA retrieved m_r is 1.61.

The retrieved value is within the expected error, particularly when the very narrow distribution (%CV ~ 1.5%) is considered.

6. REFRACTIVE INDEX OF α -PINENE SOA

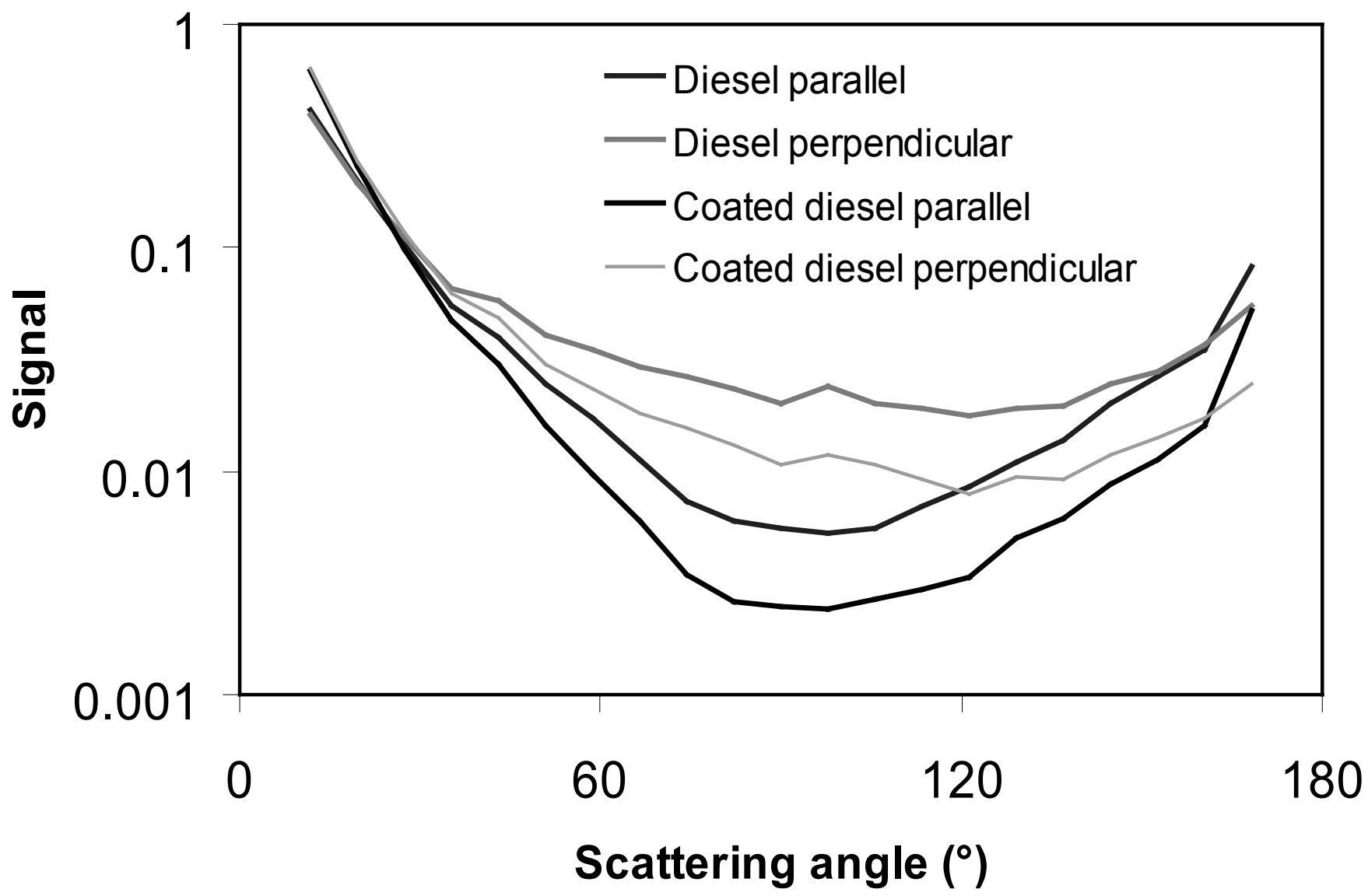


The measured scattering properties of α -pinene SOA homogeneously nucleated in a large Teflon bag. The measured SMPS average radius is 228 nm and $\sigma = 117$, assuming a log normal distribution.

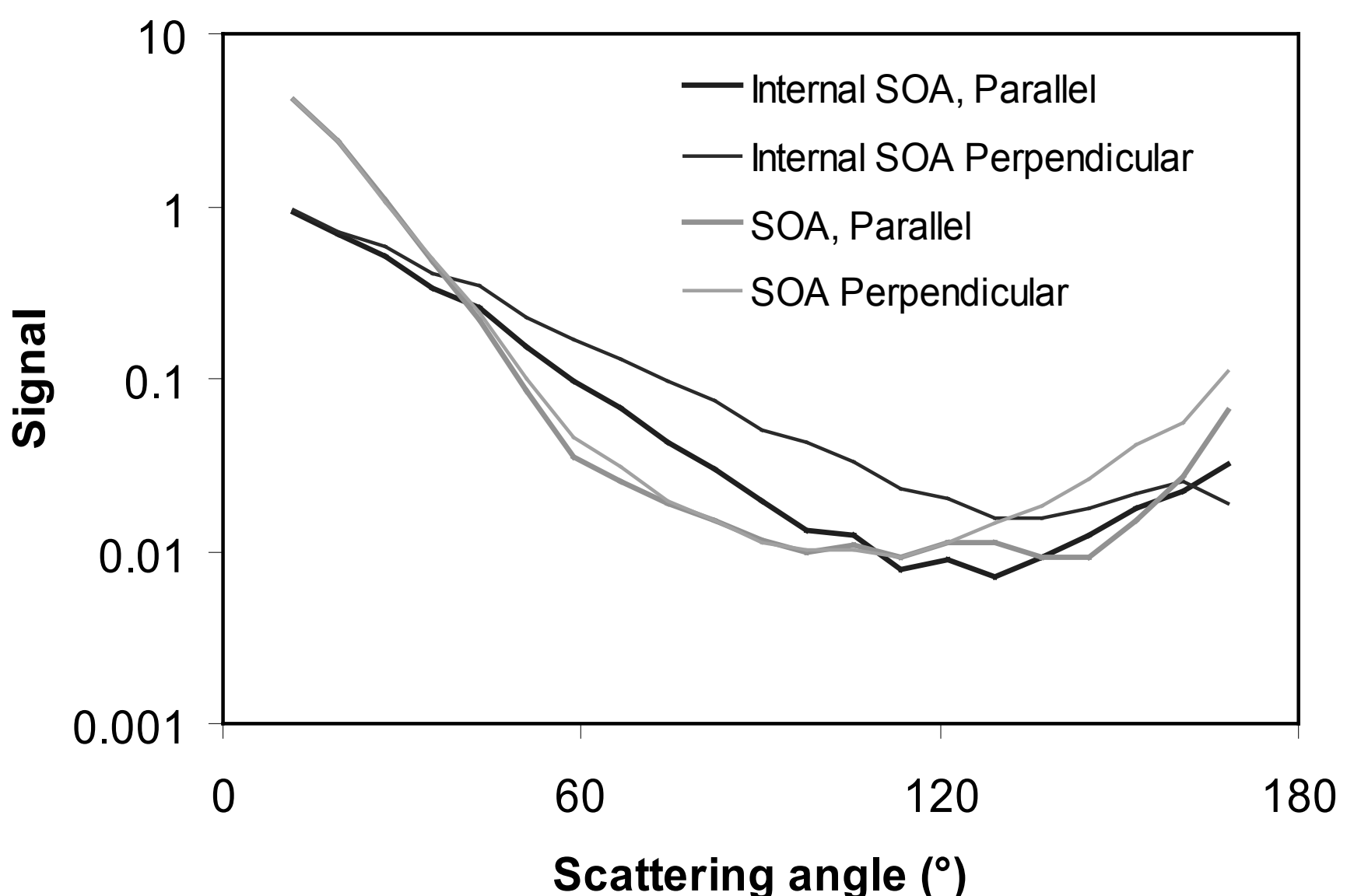
The GA retrieved $m_r = 1.41$

Although we can assume that most of the particles are spherical as shown in the image above, particle homogeneity may not be true, which could account for the differences between about 130° and 180°.

7. OTHER RESULTS: PRELIMINARY



Dual polarization scattering properties from particles generated from a small diesel generator along with those coated via a photo-chemical reaction with propene gas.



Dual polarization scattering properties from SOA generated via homogeneous nucleation of a-pinene along with similar results from SOA generated via heterogeneous nucleation of a-pinene on diesel particles.

8. SUMMARY

Several measurements of the scattering properties of test aerosols, diesel particles, coated diesel particles and SOA are presented.

Determination of the real refractive index of polystyrene latex particles are within the limits expected via an error analysis of the instrument and GA method.

Preliminary determination of the refractive index of SOA shows the limitations of assuming that aerosols are spherical and homogeneous.

Work is underway to determine the real and imaginary refractive indices of other measured aerosols using scattering solutions more representative of actual aerosol morphologies.

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- Citations
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 2. Fuller, K. A., Malm, W. C., and Kreidenweis, S. M. (1999) Effects of mixing on extinction by carbonaceous particles, J. Geophys. Res., 104:15941 - 15954.
 3. Horvath, H. (1993) Atmospheric light absorption-A review, Atmospheric Environment, 27A:293 - 317.
 4. Seinfeld, J.H. and Pandis, S.N. (1998) Atmospheric chemistry and physics; from air pollution to climate change, John Wiley & Sons, Inc., New York.